PB-240 204

BUDD LAKE, MARTIN COUNTY, MINNESOTA

Pacific Northwest Environmental
Research Laboratory

Prepared for:

National Environmental Research Center
Minnesota Pollution Control Agency
Minnesota National Guard

December 1974

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1. REPORT NO.	2.	3. PB 240 204
4. TITLE AND SUBTITLE Report on Budd Lake, Martin County, Minnesota		5. REPORT DATE Prepared December 1974 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper # 89
9. PERFORMING ORGANIZATION NAME AND ADDRESS Pacific Northwest Environmental Research Laboratory U.S.Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330		10. PROGRAM ELEMENT NO. 1BA029 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency		13. TYPE OF REPORT AND PERIOD COVERED Final - 1972 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

PRICES SUBJECT TO CHANGE

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release unlimited	20. SECURITY CLASS (This page)	22. PRICE 3.25-2.25

EPA Form 2220-1 (9-73)

REPORT

ON

BUDD LAKE

MARTIN COUNTY

MINNESOTA

EPA REGION V

WORKING PAPER No. 89

WITH THE COOPERATION OF THE

MINNESOTA POLLUTION CONTROL AGENCY

AND THE

MINNESOTA NATIONAL GUARD

DECEMBER, 1974

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

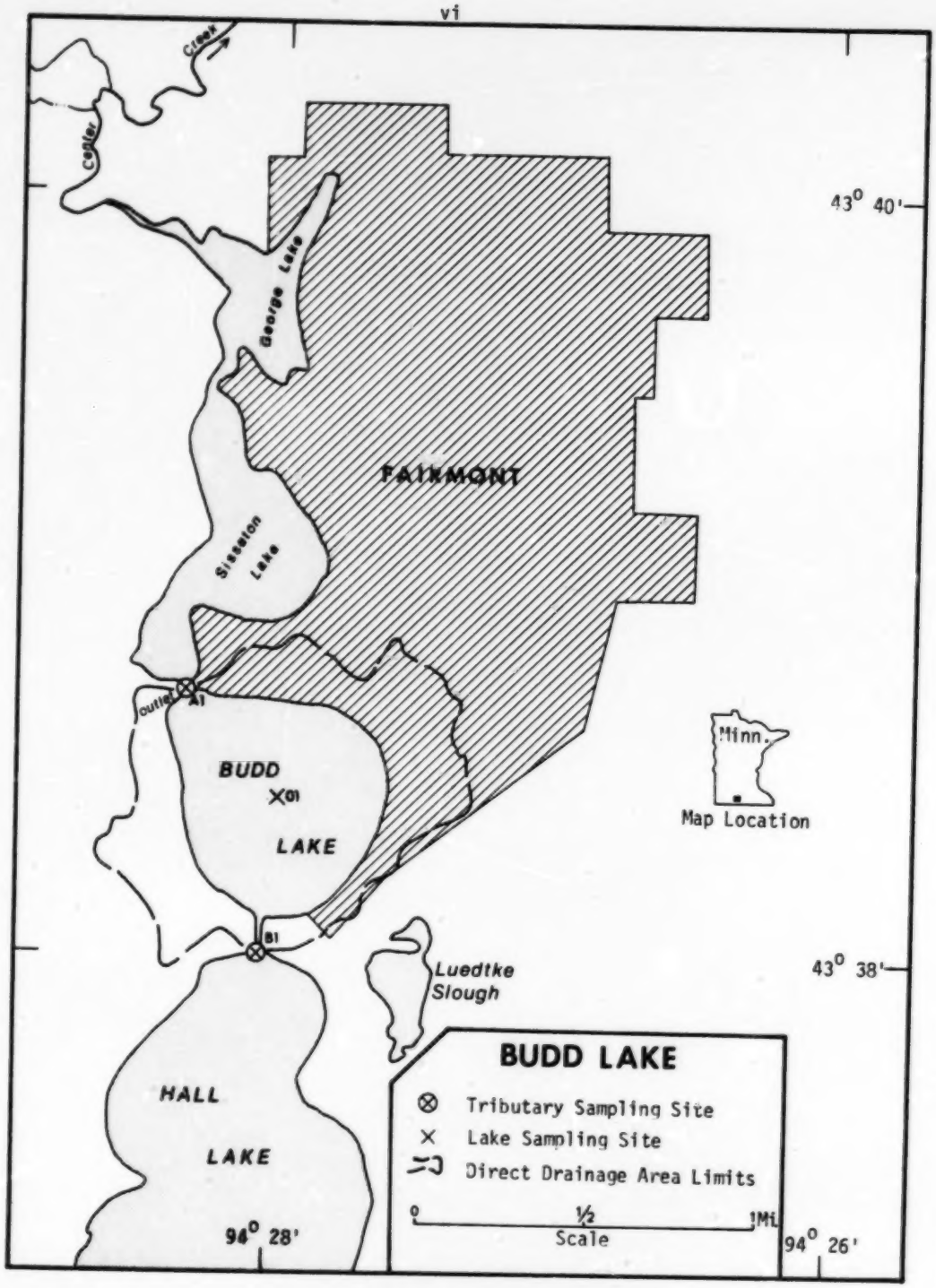
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


Creek
Cedar
George Lake
43° 40'
FAIRMONT
Sisseton Lake
Outlet A1
BUDD
LAKE
Minn.
Map Location
B1
Luedtke Slough
43° 38'
HALL
LAKE
94° 28'
94° 26'
BUDD LAKE
Tributary Sampling Site
Lake Sampling Site
Direct Drainage Area Limits
0
½
1Mi
Scale

BUDD LAKE

STORET NO. 27A8

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Miller and Smith, 1964) indicate that Budd Lake is eutrophic. Of the Minnesota lakes sampled in the fall when essentially all were well-mixed, 37 had less mean total phosphorus, 39 had less mean dissolved phosphorus, and 43 had less mean inorganic nitrogen. Of all 80 lakes sampled, 48 had less mean chlorophyll a, and 50 had greater Secchi disc transparency.

Survey limnologists noted that the lake was very turbid on all sampling trips. During the July sampling period, an algal bloom was in progress, and hydrogen sulfide was detected in the deeper samples.

B. Rate-Limiting Nutrient:

A significant loss of nutrients occurred in the algal assay sample between the time of collection and the beginning of the assay, and the results are not indicative of conditions in the lake at the time of sampling. However, the lake data show nitrogen limitation at all sampling times (N/P ratios were less than 10/1 on all occasions).

C. Nutrient Controllability:

Other than septic tanks, there were no known point sources impacting Budd Lake during the sampling year. Nonetheless, it

is calculated that Budd Lake received a total phosphorus load at a rate nearly three times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 11). Of this load, nearly 96% was contributed by the Hall Lake outlet. Hall, Amber, and Wilmert lakes are upstream water bodies, all of which have been identified as naturally eutrophic by the Minnesota Pollution Control Agency (McGuire, 1974). Therefore, there is little likelihood of control of the phosphorus load to Budd Lake.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 222 acres.
2. Mean depth: 11.4 feet.
3. Maximum depth: 17 feet.
4. Volume: 2,531 acre/feet.
5. Mean hydraulic retention time: 125 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Hall Lake - Budd Lake connection	37.0 mi^2	9.7 cfs
Minor tributaries & immediate drainage -	0.9 mi^2	0.5 cfs
Totals	37.9 mi^2	10.2 cfs

2. Outlet -

Budd Lake - Sisseton Lake connection	38.2 mi^2**	10.2 cfs

C. Precipitation:

1. Year of sampling***: 30.6 inches.
2. Mean annual: 28.5 inches.

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† DNR lake survey map (1956); mean depth by random dot method.
* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods".

III. LAKE WATER QUALITY SUMMARY

Budd Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one station on the lake and from a number of depths (see map, page vi). During each visit, a single depth-integrated (near bottom to surface) sample was collected from the station for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was collected for algal assays. Also each time, a depth-integrated sample was collected for chlorophyll a analysis. The maximum depth sampled was 13 feet.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (10/29/72)		
Temperature (Cent.)	6.5	6.5	6.5	6.6
Dissolved oxygen (mg/l)	8.6	8.7	8.7	8.9
Conductivity (μmhos)	440	440	440	440
pH (units)	7.7	7.8	7.8	7.8
Alkalinity (mg/l)	143	144	144	145
Total P (mg/l)	0.071	0.077	0.078	0.081
Dissolved P (mg/l)	0.056	0.057	0.057	0.058
NO_2 + NO_3 (mg/l)	0.360	0.377	0.370	0.400
Ammonia (mg/l)	0.120	0.137	0.130	0.160
		ALL VALUES		
Secchi disc (inches)	20	32	36	40

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/01/72	1. Anabaena	12,432
	2. Melosira	4,594
	3. Flagellates	1,802
	4. Dinobryon	1,081
	5. Cryptomonas	360
	Other genera	1,443
	Total	21,712
08/30/72	1. Anabaena	790
	2. Cyclotella	211
	3. Flagellates	163
	4. Oocystis	126
	5. Melosira	114
	Other genera	242
	Total	1,646
10/29/72	1. Anabaena	3,015
	2. Flagellates	3,015
	3. Dinobryon	1,508
	4. Scenedesmus	1,156
	5. Navicula	603
	Other genera	2,813
	Total	12,110

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
07/01/72	01	47.6
08/30/72	01	6.4
10/29/72	01	11.4

C. Limiting Nutrient Study:

There was a significant loss of nutrients in the algal assay sample between the time of collection and the beginning of the assay, and the results are not indicative of lake conditions at the time of sampling. However, the lake data show nitrogen limitation at all sampling times; i.e., N/P ratios were less than 10/1 on all occasions, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi). Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in lbs/mi^2/year, at stations C-1, E-1, G-1, and H-1 of Heron Lake and multiplying the means by the ZZ area in mi^2.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

* See Working Paper No. 1.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Hall Lake - Budd Lake connection	3,070	95.6
b. Minor tributaries & immediate drainage (non-point load) -	60	1.9
c. Known municipal - None	-	-
d. Septic tanks* -	50	1.6
e. Known industrial - None	-	-
f. Direct precipitation** -	30	0.9
Total	3,210	100.0

2. Outputs -

Lake outlet - Budd Lake - Sisseton connection	3,230

3. Net annual P loss - 20 pounds

* Estimate based on 77 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Hall Lake - Budd Lake connection	67,390	91.6
b. Minor tributaries & immediate drainage (non-point load) -	2,200	3.0
c. Known municipal - None	-	-
d. Septic tanks* -	1,810	2.5
e. Known industrial - None	-	-
f. Direct precipitation** -	2,140	2.9
Total	73,540	100.0

2. Outputs -

Lake outlet - Budd Lake Sisseton connection	74,240

3. Net annual N loss - 700 pounds

* Estimate based on 77 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
Hall Lake - Budd Lake connection	83	1,821

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (1973). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	14.5	loss*	331.3	loss*
grams/m^2/yr	1.62	-	37.1	-

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Budd Lake:

"Dangerous" (eutrophic rate)	0.62
"Permissible" (oligotrophic rate)	0.31

* There was a slight loss of phosphorus and nitrogen during the sampling year. This may be due to underestimation of septic tank contributions or may have resulted from the limits of accuracy of the flow estimates provided by U.S.G.S. (see page 3).

V. LITERATURE REVIEWED

McGuire, John F., 1974. Personal communication (trophic state of Hall, Amber, and Wilmert lakes). MPCA, Minneapolis.

Miller, Richard D., and Wesley E. Smith, 1964. Report on follow-up survey of the Fairmont Lakes, Martin County. MPCA, Minneapolis.

Schilling, Joel, 1974. Personal communication (lake map). MPCA, Minneapolis.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. A. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 27AA WOOD LAKE

TOTAL DRAINAGE AREA OF LAKE 39.20

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
27AAA1	39.20	1.22	2.05	13.16	23.56	18.46	18.56	16.32	8.25	11.12	4.83	2.42	2.32	10.22
27AAB1	37.00	1.16	1.96	12.40	22.40	17.40	17.60	15.50	7.77	10.50	4.55	2.27	2.22	9.70
27AAZZ	1.23	0.05	0.07	0.50	1.02	0.98	0.99	0.91	0.43	0.79	0.28	0.12	0.12	0.52

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 39.20
SUM OF SUB-DRAINAGE AREAS = 38.23

TOTAL FLOW IN = 122.41
TOTAL FLOW OUT = 122.27

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
27AAA1	10	72	5.21	14	4.90				
	11	72	3.75						
	12	72	4.43	10	5.60				
	1	73	6.02						
	2	73	5.27						
	3	73	53.30	10	47.00				
	4	73	37.80	30	17.00				
	5	73	18.20	18	25.00				
	6	73	6.72	14	61.00				
	7	73	6.72						
	8	73	2.02	5	2.63				
	9	73	2.29	4	1.58				
	10	73	2.29						
27AAB1	10	72	5.00	14	4.70				
	11	72	2.63						
	12	72	4.50	10	5.50				
	1	73	5.94						
	2	73	5.16						
	3	73	52.90	10	47.00				
	4	73	36.40	30	17.00				
	5	73	17.60	18	25.00				
	6	73	6.51	14	59.00				
	7	73	6.51						
	8	73	1.94	5	2.52				
	9	73	2.23	4	1.52				
	10	73	2.20						

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TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2748 HOOD LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2748ZZ	10	72	0.31	14	0.30				
	11	72	0.14						
	12	72	0.24	10	0.30				
	1	73	0.25						
	2	73	0.18						
	3	73	2.07	16	1.80				
	4	73	2.15	30	0.80				
	5	73	0.49	18	1.40				
	6	73	0.38	14	3.30				
	7	73	0.38						
	8	73	0.11	5	0.14				
	9	73	0.17	4	0.11				

A-2

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

27A801
47 40 55.0 096 00 28.0
BUDD LAKE
27 MINNESOTA

11EPALES
3

2111202
0015 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/01	16 20	0000	25.0	13.8	36	385	9.00	132	0.050	0.060	0.125	0.070
	16 20	0013	19.5	0.0		440	7.60	159	0.120	1.400	0.520	0.488
72/08/30	15 50	0000			40	400	8.40	137	0.050	0.700	0.260	0.240
	15 50	0004	21.6	6.8		390	8.30	136	0.050	0.680	0.260	0.236
	15 50	0010	20.0	1.8		420	7.80	139	0.050	1.200	0.311	0.300
72/10/29	10 00	0000			20	440	7.80	143	0.370	0.120	0.071	0.056
	10 00	0004	6.6	8.9		440	7.80	144	0.360	0.130	0.078	0.058
	10 00	0010	6.5	8.6		440	7.70	145	0.400	0.160	0.081	0.057

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/01	16 20	0000	47.6J
72/08/30	15 50	0000	6.4J
72/10/29	10 00	0000	11.4J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

27ABA1 LS27ABA1
43 38 30.0 094 28 30.0
SISSETON LK/BUDD LK CONNECTION
27 7.5 FAIRMONT
O/BUDD LAKE
BIRD BRDG SW EDGE OF FAIRMONT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	08	25	0.330	1.850	0.180	0.040	0.152
73/01/17	13	25	0.610	1.050	0.096	0.042	0.063
73/03/10	14	55	1.620	1.320	0.026	0.014	0.095
73/04/30	14	30	1.840	2.520	0.098	0.008	0.070
73/05/18	09	00	1.880	1.100	0.096	0.018	0.085
73/06/14	14	35	2.400	7.300	0.700	0.018	0.065
73/08/05	09	30	0.021	4.600	0.310	0.058	0.175
73/09/04	09	30	0.012	2.300	0.038	0.140	0.310
73/10/02	15	25	0.100	3.600	0.132	0.189	0.525

C-2

STORET RETRIEVAL DATE 74/10/30

27ABBI LS27ABBI
43 38 00.0 094 28 00.0
HALL LK/HUDD LK CONNECTION
27 7.5 FAIRMONT
I/HUDD LAKE
LAIR RD BRDG S OF FAIRMONT
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/14	14 45		0.360	1.200	0.150	0.058	0.115
72/12/10	14 15		1.060	0.800	0.078	0.023	0.040
73/01/17	13 35		0.900	1.200	0.245	0.041	0.055
73/03/10	15 30		2.200	1.500	0.026	0.010	0.095
73/04/30	14 40		2.300	1.260	0.012	0.011	0.095
73/05/18	09 10		2.900	0.940	0.099	0.022	0.095
73/06/14	14 45		2.800	6.700	0.570	0.008	0.065
73/08/05	10 00		0.010K	3.780	0.057	0.042	0.198
73/09/04	09 35		0.105	2.700	0.990	0.130	0.280
73/10/02	15 33		0.010K		0.052	0.189	0.690

K VALUE KNOWN TO BE LESS THAN INDICATED